QP CODE: 77300

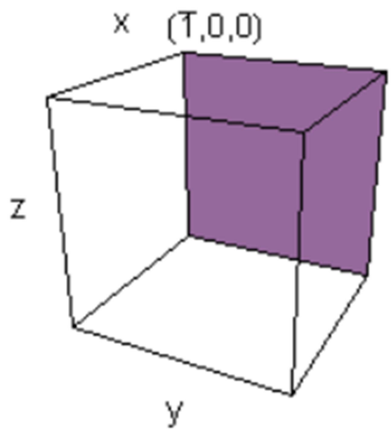
PHYSICS SOLUTION

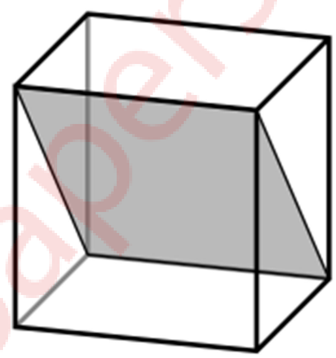
SEM – 1 (Rev- 2019'C' Scheme DEC – 2019)

Q1] Attempt any five questions from the following **(15)**

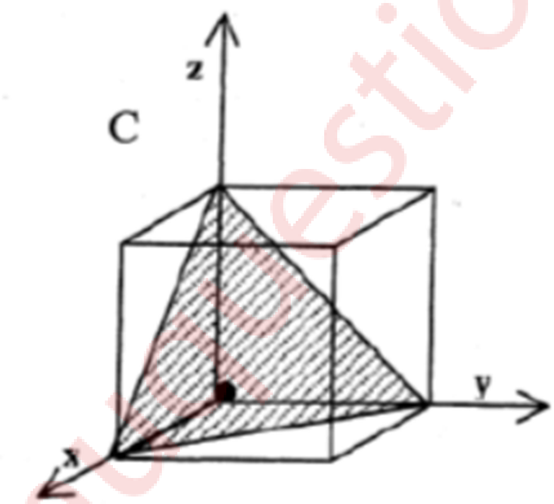
a) Draw $(\mathbf{0\ 0\ 2}), (\bar{\mathbf{1}}\ \mathbf{0\ 0}), (\mathbf{0\ 1\ 1})$

Solution :-





(011)



(0 0 2)

(b) Explain any three properties of matter waves.

Solution :-

(1) Matter wave represents the probability of finding a particle in space.

(2) Matter waves are not electromagnetic in nature.

(3) de-Brogile or matter wave is independent of the charge on the material particle. It means, matter wave of de-Broglie wave is associated with every moving particle (whether charged or uncharged).

(4) Practical observation of matter waves is possible only when the de-Broglie wavelength is of the order of the size of the particles.

(5) Electron microscope works on the basis of de-Broglie waves.

(6) The phase velocity of the matter waves can be greater than the speed of the light.

(7) Matter waves can propagate in vacuum, hence they are not mechanical waves.

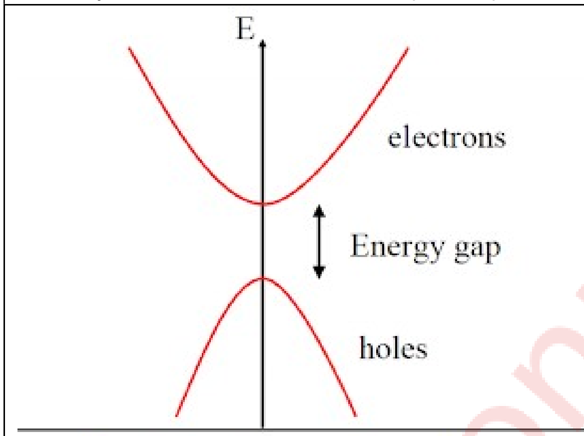
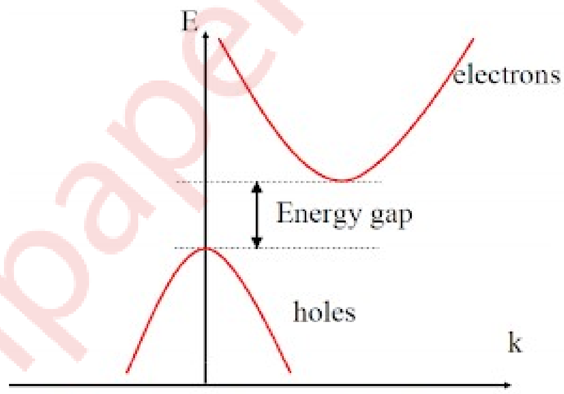
(8) The number of de-Broglie waves associated with nth orbital electron is n.

(9) Only those circular orbits around the nucleus are stable whose circumference is integral multiple of de-Broglie wavelength associated with the orbital electron.

(c) Differentiate between Direct and Indirect band gap semiconductor.

Solution:-

Direct band gap semiconductor	**Indirect band gap semiconductor**
A direct band-gap (DBG) semiconductor is one in which the maximum energy level of the valence band aligns with the minimum energy level of the conduction band with respect to momentum.	An Indirect band-gap (IBG) semiconductor is one in which the maximum energy level of the valence band and the minimum energy level of the conduction band are misaligned with respect to momentum.
In a DBG semiconductor, a direct recombination takes place with the	In case of a IBG semiconductor, due to a relative difference in the

release of the energy equal to the energy difference between the recombining particles.	momentum, first, the momentum is conserved by release of energy and only after the both the momenta align themselves, a recombination occurs accompanied with the release of energy.
The probability of a radiative recombination is high.	The probability of a radiative recombination is comparatively low.
The efficiency factor of a DBG semiconductor is higher. Thus, DBG semiconductors are always preferred over IBG for making optical sources.	The efficiency factor of a IBG semiconductor is lower.
Example, Gallium Arsenide (GaAs).	Example, Silicon and Germanium
 Direct bandgap semiconductors	 Indirect bandgap semiconductors

(d) Explain any three conditions for Sustained Interference.

Solution:-

To obtain well defined interference patterns, the intensity at points corresponding to destructive interference must be zero, while intensity at the point corresponding to constructive interference must be maximum. To accomplish this the following conditions must be satisfied.

- The two interfering sources must be coherent, that is, they must keep a constant phase difference.

- The two interfering sources must emit the light of the same wavelength and time period. This condition can be achieved by using a monochromatic common original source, that is, the common source emits light of a single wavelength.
- The amplitudes or intensities of the interfering waves must be equal or very nearly equal so that the minimum intensity would be zero.
- The separation between the two coherent sources must be as small as possible so that the width of the fringes is large and are separately visible.
- The two sources must be narrow or they must be extremely small. A broad source is equivalent to a large number of fine sources. Each pair of fine sources will give its own pattern. The fringes of different interference patterns will overlap.
- The distance between the two coherent sources and the screen must be as large as possible so that the width of fringes is large and are separately visible.
- The two interference waves must be propagated along the same direction so that their vibrations are along a common line.

(e) A source is emitting 150W of red light of wavelength of 600nm. How many photons per second are emerging from the source.

Solution :-

$$E = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34})\times(3\times10^{8})}{600\times10^{-9}} = 3.313\times10^{-19}J$$

$$E = 3.313\times10^{-19}J$$

Each photons carry $3.313\times10^{-19}J$ of energy

A 100W source means that it output 100 Joules of energy every second

No of photons emitted = total energy output in one second/ energy carried per photon

$$n = \frac{150}{3.313\times10^{-19}} = 4.527\times10^{20}$$

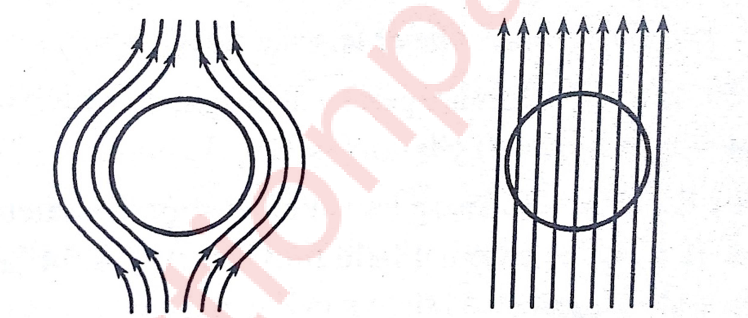
Answer :- 4.527×10^{20}

(f) Explain the Meissner effect with application.

Solution :-

A superconducting material kept in a magnetic field expels the magnetic flux out its body when cooled below the critical temperature and exhibits perfect diamagnetism. This is called MEISSNER EFFECT.

- It is found that as the temperature of the specimen is lowered to T_c, the magnetic flux is suddenly and completely expelled from it. The flux expulsion continues for $T < T_c$. The effect is reversible.
- When the temperature is raised from below T_c. The flux density penetrates the specimen again at $T = T_c$ and the material turns to the normal state.



(a) Superconducting state at $T < T_c$ or $H < H_c$

(b) Normal state at $T > T_c$ or $H > H_c$

- For the normal state the magnetic induction inside the specimen is given by:
  $B = \mu_o(H + M) = \mu_O(1 + \chi)H$……………………………………….(1)

Here H is the applied magnetic field , m is the magnetization produced within the specimen , is χ the susceptibility of the material and μ_o is the permeability of free space.

- At $T < T_c$ as seen above
  B = 0

$M = -H$

And thus $\chi = \frac{M}{H} = -1$

- The specimen is therefore a perfect diamagnetic. The diamagnetism produces strong repulsion to the external magnets.
- This effect is used to identify a superconductor , in levitation effect and suspension effect.

(g) Explain Magento Resistance with application.

Solution :-

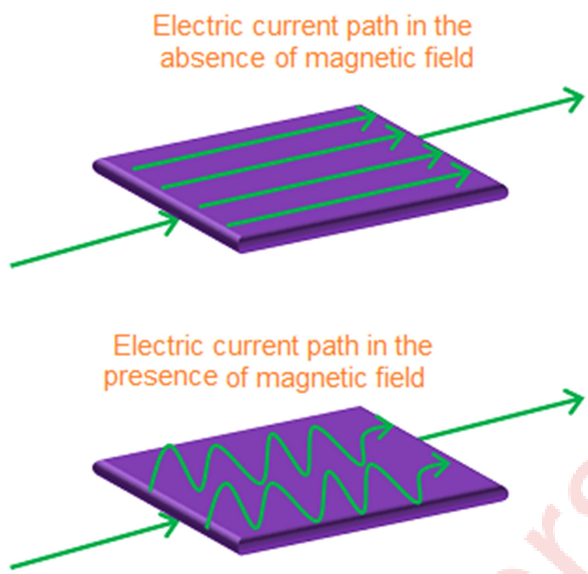
<u>Magneto resistor definition</u>

Magneto resistor is a type of resistor whose resistance changes when an external magnetic field is applied. In other words, the flow of electric current through the magneto resistor changes when an external magnetic field is applied to it. Magnetic field is the region present around a magnetic object within which other objects experience an attractive or repulsive force.

Magneto resistive effect is the property of some materials, which causes them to change their resistance under the presence of magnetic field. This magneto resistive effect occurs in materials such as semiconductors, non-magnetic metals, and magnetic metals.

An Irish mathematical physicist and engineer William Thomson first discovered this magneto resistive effect in 1856. He observed that resistance of the pieces of iron increased when the electric current is flowing in the same direction as the magnetic force or magnetic field and the resistance is decreased when the electric current is flowing at 90° to the magnetic field or magnetic force.

After that, he performed the same experiment with nickel and he found that the resistance of the nickel is affected in the same manner but the magnitude of this magnetic field was much greater than before. This effect is called Anisotropic Magneto Resistance (AMR).



Applications of magneto resistors

The various applications of magneto resistors include:

- Bio-sensors
- Hard disk drives
- Magnetic field sensors
- Magneto resistors are used in electronic compass for measuring earth's magnetic field.
- Magneto resistors are used for measuring electric current.

Q2] A) show that Non-Existence of electron in the Nucleus, Find the uncertainty in the position of electron. The speed of an electron is measured to be 4×10^3 m/s to an accuracy of 0.002% (8)

Solution :-

Initially assume that an electron is a part of a nucleus. The size of a nucleus is about 1 fermi = 10^{-15}m if an electron is confined within a nucleus the uncertainty in its position must not be greater than the dimension of the nucleus i.e., 10^{-15}m. hence, $\Delta x_m = 10^{-15}$m

From the limiting condition of Heisenberg's uncertainty principle given in the equation it can be written as

$$\Delta x_m . \Delta p_{mi} = \hbar$$

$$\Delta p_{mi} = \frac{\hbar}{\Delta x_{mi}} = \frac{6.63 \times 10^{-34}}{2 \times 3.14 \times 10^{-15}} = 1.055 \times 10^{-19} \text{kg-m/sec}$$

$$\text{Now , } \Delta p_{mi} = m \Delta v_{mi}$$

$$\text{Hence , } \quad \Delta v_{mi} = \frac{\Delta p_{mi}}{m} = \frac{1.055 \times 10^{-19}}{9.1 \times 10^{-31}} = 1.159 \times 10^{11} \text{m/s} > c$$

$$\text{As , } \Delta v_{mi} < v \text{ , } v > 1.159 \times 10^{11} \text{m/s} > c$$

Therefore the electron inside the nucleus behaves as a relativistic particle.

The relativistic energy of the electron is $E = \sqrt{m_o^2 c^4} + \sqrt{p^2 c^2}$

Since the actual momentum of the electron p>> $\Delta p_{mi} . p^2 . c^2 \gg m_o^2 . c^2$, the rest mass energy of the electron the value of which is 0.511 MeV. Hence, E= pc

Assuming p = Δp_{mi} the least energy that an electron should posses within a nucleus is given by

$$E_{mi} = \Delta p_{mi} . c$$

$$= 1.055 \times 10^{-19} \times 3 \times 10^8$$

$$= 3.165 \times 10^{-11} \text{J}$$

$$E_{mi} = \frac{3.165 \times 10^{-1}}{1.6 \times 10^{-19}} = 197 \text{ MeV.}$$

In reality the only source of generation of electron with in a nucleus is the process of β-decay. The maximum kinetic energy possessed by the electrons during β-decay is about 100KeV. This shows that an electron can not exist within a nucleus.

NUMERICAL:-

Given Data :- V $= 4 \times 10^3$ m/sec , $\frac{\Delta v}{v} = ?$ $\Delta x = 0.002\%$

Formula :- $\Delta x . \Delta p \geq \hbar$

Calculations :- $\Delta x . m . \Delta p \geq \hbar$

$$\Delta x \geq \frac{\hbar}{m \Delta v}$$

$$\Delta v = \frac{6.63 \times 100 \times 10^{-34}}{0.002 \times 2 \times 3.14 \times 9.1} = 0.58 \times 10^{-30}$$

Uncertainty :-

$$\frac{\Delta v}{v} = \frac{(0.58 \times 10^{-30})}{4 \times 10^3} = 1.45 \times 10^{-34}$$

Therefore uncertainty in position = $\mathbf{1.45 \times 10^{-34}}$

Q2] B) Define the Fermi energy level, show that in intrinsic semiconductor Fermi level is at the centre of Forbidden energy gap. Draw the position of Fermi level in intrinsic, P type and N type semiconductor. (7)

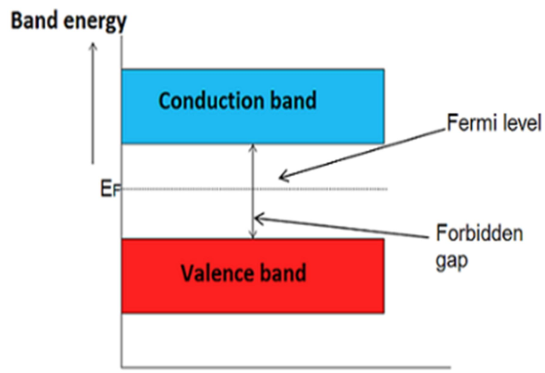
Solution :-

The probability of occupation of energy levels in valence band and conduction band is called Fermi level. At absolute zero temperature intrinsic semiconductor acts as perfect insulator. However as the temperature increases free electrons and holes gets generated.

In intrinsic or pure semiconductor, the number of holes in valence band is equal to the number of electrons in the conduction band. Hence, the probability of occupation of energy levels in conduction band and valence band are equal. Therefore, the Fermi level for the intrinsic semiconductor lies in the middle of forbidden band.

Fermi level in the middle of forbidden band indicates equal concentration of free electrons and holes.

The hole-concentration in the valence band is given as



$$p = N_V e^{\frac{-(E_F - E_V)}{K_B T}}$$

The electron-concentration in the conduction band is given as

$$n = N_c e^{\frac{-(E_C - E_F)}{K_B T}}$$

Where K_B is the Boltzmann constant

T is the absolute temperature of the intrinsic semiconductor

N_c is the effective density of states in the conduction band.

N_v is the effective density of states in the valence band.

The number of electrons in the conduction band is depends on effective density of states in the conduction band and the distance of Fermi level from the conduction band.

The number of holes in the valence band is depends on effective density of states in the valence band and the distance of Fermi level from the valence band.

For an intrinsic semiconductor, the electron-carrier concentration is equal to the hole-carrier concentration.

It can be written as

p = n = ni

Where P = hole-carrier concentration, n = electron-carrier concentration and n_i = intrinsic carrier concentration

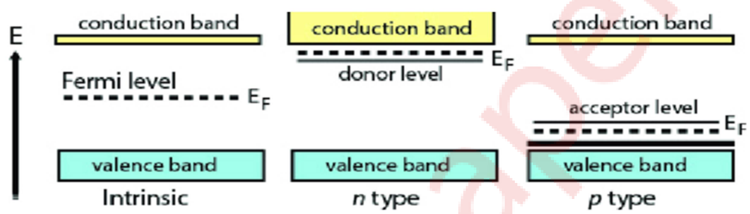
The fermi level for intrinsic semiconductor is given as,

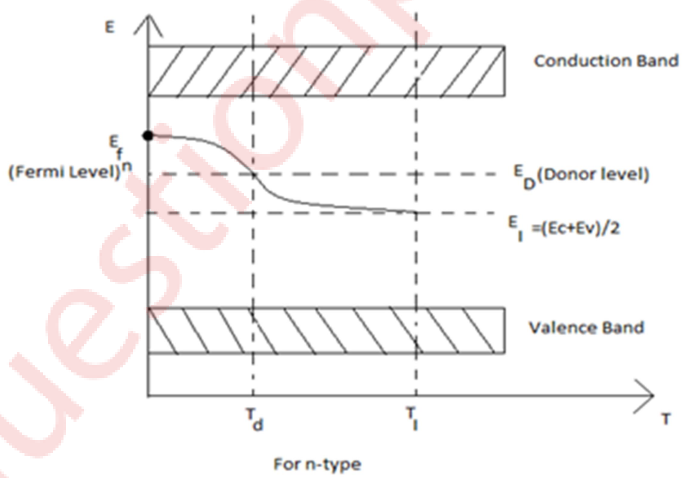
$$E_F = \frac{E_C + E_V}{2}$$

Where E_F is the fermi level
E_C is the conduction band
E_V is the valence band

Therefore, the Fermi level in an intrinsic semiconductor

lies in the middle of the forbidden gap.



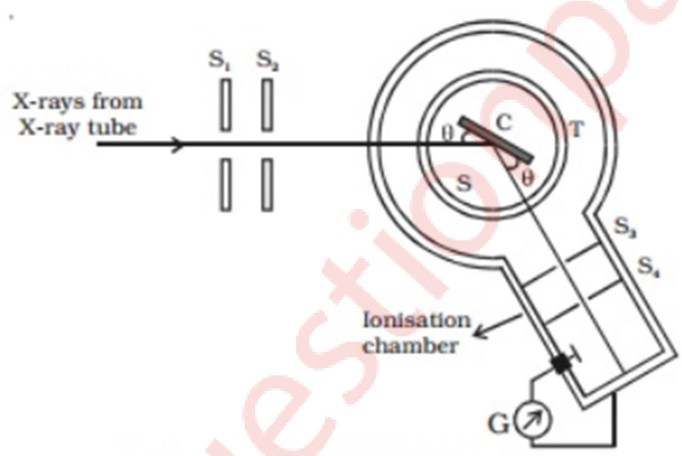


Q3] A) Explain with diagram Bragg's X ray Spectrometer. Calculate the interplaner spacing between the family of planes (1 1 1) in crystal of lattice constant 3A° **(8)**

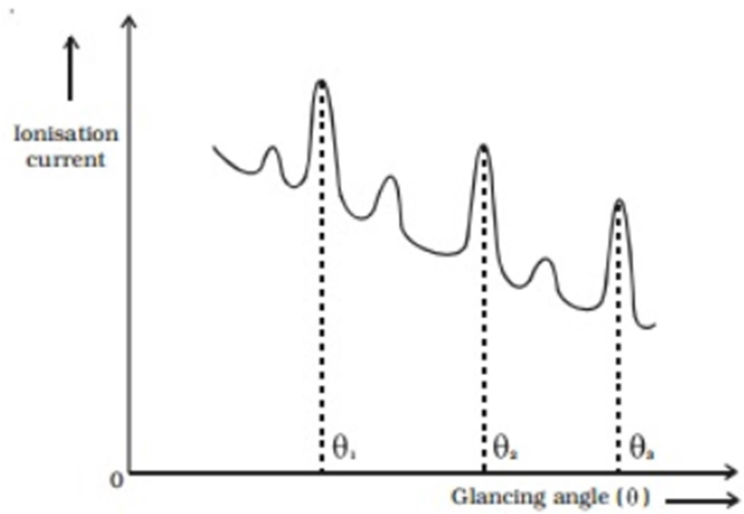
Bragg's spectrometer used to determine the wavelength of X - rays is shown in Fig. Bragg's spectrometer is similar in construction to an ordinary optical spectrometer.

X-rays from an X-ray tube are made to pass through two fine slits S_1 and S_2 which collimate it into a fine pencil. This fine X-ray beam is then made to fall upon the crystal 'C' (usually sodium chloride crystal) mounted on the spectrometer table. This table is capable of rotation about a vertical axis and its rotation can be read on a circular graduated scale S. The reflected beam after passing through the slits S_3 and S_4 enters the ionization chamber. The X-rays entering the ionization chamber ionize the gas which causes a current to flow between the electrodes and the current can be measured by galvanometer G. The ionization current is a measure of the intensity of X-rays reflected by the crystal.

The ionization current is measured for different values of glancing angle θ. A graph is drawn between the glancing angle θ and ionization current.



For certain values of glancing angle,the ionization current increases abruptly. The first peak corresponds to first order, the second peak to second order and so on. From the graph, the glancing angles for different orders of reflection can be measured. Knowing the angle θ and the spacing d for the crystal, wavelength of X-rays can be determined.



NUMERICAL :-

$(h\,l\,k) = (1\;1\;1)$

$a = 3A°$

To find :-

Inter- planar distance (d)

Solution:-

We know that,

$$d = \frac{a}{\sqrt{h^2+k^2+l^2}} = \frac{3}{\sqrt{1^2+1^2+1^2}} = \sqrt{3}$$

$d = 1.732A°$

Q3] B) Prove that the Diameter of the nth dark ring in Newton's ring setup is directly proportional to the square root of the ring number. In Newton's Rings reflected light of wavelength 5×10^{-5} cm. the diameter of the 10th dark ring is 0.5cm. calculate radius of curvature R. **(7)**

Solution :-

Let POQ be the plano-convex lens placed on a plane glass plate AB. Let R be the radius of curvature of the lens surface in contact with the plate.

Let p be the radius of a Newton's ring corresponding to the constant film thickness 't'. The path difference between the two interfering rays in the reflected system is

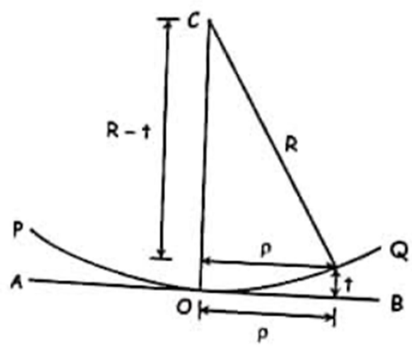
$2\mu\cos(r+\theta)+\frac{\lambda}{2}$

λ = wavelength of incident light

$\mu = 1$ for air film

$r = 0$ for normal incidence

$\theta = 0$ for large R



From diagram

$R^2 = p^2 + (R-t)^2$

$p^2 = R^2 - (R-t)^2$

$p^2 = 2Rt - t$

$t \ll R$ and hence we have

$p^2 = 2Rt$

Path difference between the interfering ray is $\frac{p^2}{R}+\frac{\lambda}{2}$

For dark rings :-

Path difference = $\frac{p^2}{R}+\frac{\lambda}{2} = (2n+1)\left(\frac{\lambda}{2}\right)$ (n=1,2,3 ....)

If D is the difference of Newton's ring then $p = \frac{D}{2}$

$\frac{D_n^2}{4R} = n\lambda \quad$ where $D_n =$ Diameter of n^{th} dark ring

$D_n^2 = 4Rn\lambda$

$D_n \propto \sqrt{n}$

Hence the diameter of the dark ring is proportional to the square root of natural numbers.

NUMERICAL :-

$D_{10} = 0.5cm$

$\lambda = 5 \times 10^{-5}$ cm

R = ?

$D_n = \sqrt{(2n-1)(2\lambda R)}$

$D_{10} = \sqrt{(2 \times 10 - 1)(2\lambda R)}$

$0.5 = \sqrt{(2 \times 10 - 1)(2 \times 5 \times 10^{-5} \times R)}$

$0.5^2 = 19 \times 10 \times 10^{-5} \times R$

$R = 131.57cm$

Q4] A) Derive one dimensional time independent Schrodinger Equation (5)

Solution :-

We start with the one-dimensional classic wave equation,

$\frac{\partial^2 u}{\partial x^2} = \frac{1}{u^2}\frac{\partial^2 u}{\partial t^2}$

By introducing the separation of variables ,

$$u(x,t) = \psi(x)f(t)$$

We obtain $f(t)\frac{d^2\psi(x)}{\partial x^2} = \frac{1}{u^2}\psi(x)\frac{d^2f(t)}{dt^2}$

If we introduce one of the standard wave equation solutions for f(t) such as $e^{i\omega t}$ (the constant can be taken care of later in the normalization), we obtain

$$\frac{d^2\psi(x)}{\partial x^2} = \frac{-\omega^2}{u^2}\psi(x)$$

Now we have an ordinary differential equation describing the spatial amplitude of the matter wave as a function of position. The energy of a particle is the sum of kinetic and potential parts.

$$E^2 = \frac{p^2}{2m} + V(x)$$

Which can be solved for the momentum (p) to obtain

$$p = \{2m[E - V(x)]\}^{1/2}$$

Now we can use the de Broglie formula to get an expression for the wavelength

$$\lambda = \frac{h}{p} = \frac{h}{\{2m[E-V(x)]\}^{1/2}}$$

The term $\frac{\omega^2}{u^2}$ in equation can be written in terms of λ if we recall that $\omega = 2\pi v$ and $v\lambda = v$

$$\frac{\omega^2}{u^2} = \frac{4\pi^2v^2}{u^2} = \frac{4\pi^2}{\lambda^2} = \frac{2m[E-V(x)}{h^2}$$

When is almost always written in the form

$$\frac{-h^2}{2m}\frac{d^2\psi(x)}{dx^2} + V(x)\psi(x) = E\psi(x)$$

A two-body problem can also be treated by this equation if the mass m is replaced with a reduced mass μ

Q4] B) Differentiate between Type I and Type II superconductor (5)

Solution :-

TYPE I SUPERCONDUCTOR	TYPE II SUPERCONDUCTOR
1. They exhibit complete Meissner effect	1. They exhibit partial Meissner effect.
2. These are perfect diamagnetics.	2. These are not perfect diamagnetics.
3. These are known as soft superconductors.	3. These are known as hard superconductors.
4. These materials undergoes a sharp transition from the superconducting state of the normal state at the critical magnetic field.	4. These materials undergoes a gradual transition from the superconducting state of the normal state at the critical magnetic field.
5. The highest value of critical magnetic field Is 0.1 wb/M2.	5. The upper critical field can be of the order of 50 wb/m2.
6. Applications are very limited.	6. They are used to generate very high magnetic field.
7. Examples:- lead tin, mercury, etc.	7. Examples:- alloys like Nb-Sn, Nb-D, Nb- Zr, etc.

Q4] C) Find Resistance of an intrinsic Ge rod of dimension(1cm long, 1mm wide and 1mm thick) at 300K. For Ge $\mathbf{n_i = 2.5 \times 10^{19}\ /m^3,\ \mu_n = 0.39\frac{m^2}{v} - s,\ \mu_p = 0.19\frac{m^2}{v} - s}$ (5)

Solution :-

$n_i = 2.5 \times 10^9\ /m^3$

$\mu_e = 0.39 \frac{m^2}{V} sec$

$\mu_h = 0.91 \frac{m^2}{V} sec$

$T = 300°K$

$l = 10^{-2} m$

$A = bd = 10^{-6} m^2$

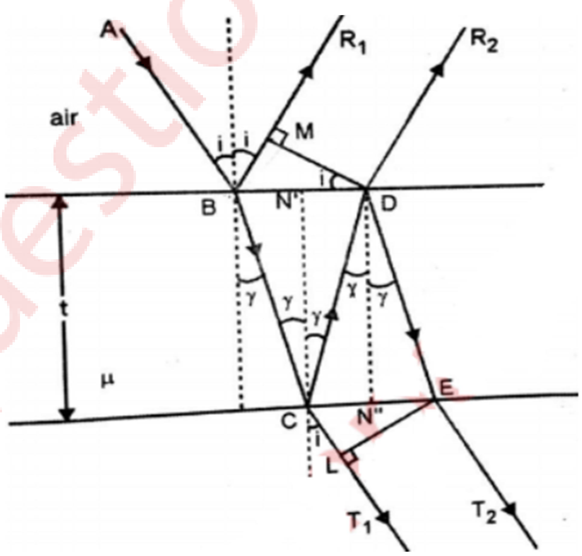
$\sigma = n_i e(\mu_e + \mu_h) = (2.5 \times 10^9)(1.6 \times 10^{-1})(0.39 + 0.19) = 2.32/\Omega m$

$\rho = \frac{1}{\sigma} = \frac{1}{2.3} = 0.431\Omega m$

$R = \rho\left(\frac{l}{A}\right) = (0.431\Omega m) \times \frac{10^{-2}}{10^{-6}} = 4.31 \times 10^3 \Omega$

Q5] A) Derive the condition for maxima and minima due to interference of light reflected from thin film of uniform thickness (5)

Solution :-



Consider a thin film of uniform thickness (t) and R.I (μ)

On Reflected side,

The ray of light R1 and R2 will interfere.

The path difference between R1 and R2 is,

$\Delta = \mu(BC + CD) - BG$

$BC = CD = \frac{t}{\cos r}$..........(1)

Now,

$BD = (2t) \tan r$ ....(2)

$BM = BD \sin i$

$BM = (2t) \tan r \sin i$

$BM = 2t\mu \sin r \left(\frac{\sin r}{\cos r}\right)$

$BM = 2\mu t \left(\frac{\sin 2r}{\cos r}\right)$..........(3)

Substituting (i) and (iii) in Δ :

$\Delta = \mu(\frac{t}{\cos r} + \frac{t}{\cos r}) 2\mu t \left(\frac{\sin 2r}{\cos r}\right)$

$= 2\mu t \cos r(1 - \sin 2r)$

$\Delta = 2\mu t \cos r$

For transmitted system :

The transmitted rays CT1 and ET2 are also derived from the same incident ray AB and hence they are coherent.

Path difference = $\triangle = \mu(CD + DE) - CL$

For constructive interference :

$2\mu t \cos r = n\lambda$

For destructive interference :

$2\mu t \cos r = (2n - 1)\lambda/2$

Q5] B) Explain Hall Effect. Derive the equation for Hall Voltage (5)

Solution :-

If a current carrying conductor or semiconductor is placed in a transverse magnetic field, a potential difference is developed across the specimen in a direction perpendicular to both the current and magnetic field. The phenomenon is called HALL EFFECT.

As shown consider a rectangular plate of a p-type semiconductor of width 'w' and thickness 'd' placed along x-axis. When a potential difference is applied along its length 'a' current 'I' starts flowing through it in x direction.

As the holes are the majority carriers in this case the current is given by

$$I = n_h A e v_d \quad \text{.................................(1)}$$

where n_h = density of holes

A = w × d = cross sectional area of the specimen

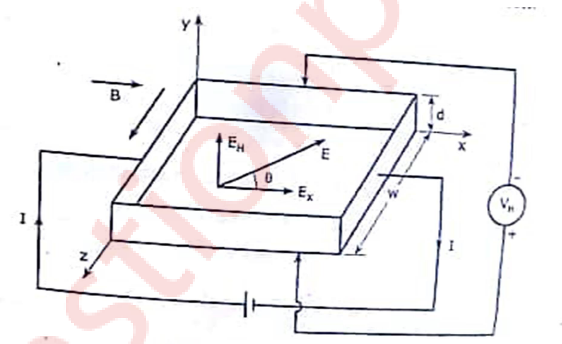


Figure 3.25 : Hall effect set up

v_d = drift velocity of the holes.

The current density is

$$J = \frac{I}{A} = n_h e v_d \quad \text{..........................(2)}$$

The magnetic field is applied transversely to the crystal surface in z direction. Hence the holes experience a magnetic force

$$F_m = e v_d B \quad \text{.................................(3)}$$

In a downward direction. As a result of this the holes are accumulated on the bottom surface of the specimen.

Due to this a corresponding equivalent negative charge is left on the top surface.

The separation of charge set up a transverse electric field across the specimen given by,

$$E_H = \frac{V_H}{d} \quad \text{................................(4)}$$

Where V_H is called the HALL VOLTAGE and E_H the HALL FIELD.

In equilibrium condition the force due to the magnetic field B and the force due to the electric field E_H acting on the charges are balanced. So the equation (3)

$$eE_H = ev_d B$$

$$E_H = v_d B \quad \text{....................................(5)}$$

Using equation (4) in the equation (5)

$$V_H = v_d B\, d \quad \text{..............................(6)}$$

From equation (1) and (2), the drift velocity of holes is found as

$$v_d = \frac{I}{en_h A} = \frac{J}{en_h} \quad \text{.........................(7)}$$

Hence hall voltage can be written as

$$V_H = \frac{IBd}{en_h A} = \frac{J_x Bd}{en_h}$$

Q5] C) Calculate the lowest three energy states of an electron confined in potential well of width 10A° **(5)**

Solution :-

Potential well width :- 10 A°

L = 10 A° $= 10 \times 10^{-10}$m

Energy of electron in n^{th} level → $E_n = \frac{n^2h^2}{8mL^2} = n^2E_1$

$$E_1 = \frac{h^2}{8mL^2} = \frac{(6.63\times10^{-34})^2}{8\times9.1\times10^{-31}\times(10\times10^{-10})^2} = \frac{43.9569\times10^{-1}}{7280} = 6.0380 \times 10^{-20}\text{J}$$

$$E_2 = n^2E_1 = 2^2E_1 = 2^2 \times 6.0380 \times 10^{-20} = 24.152 \times 10^{-20}\text{J}$$

$$E_3 = n^2E_1 = 3^2E_1 = 3^2 \times 6.0380 \times 10^{-20} = 54.342 \times 10^{-20}\text{J}$$

Q6] A) Explain multiferroics and its different types (5)

Solution :-

Multiferroics are defined as materials that exhibit more than one of the primary ferroic properties:

- ferromagnetism—a magnetisation that is switchable by an applied magnetic field,
- ferroelectricity—an electric polarisation that is switchable by an applied electric field, and
- ferroelasticity—a deformation that is switchable by an applied stress,

in the same phase. While ferroelecstric ferroelastics and ferromagnetic ferroelastics are formally multiferroics, these days the term is usually used to describe the magnetoelectric multiferroics that are simultaneously ferromagnetic and ferroelectric. Sometimes the definition is expanded to include non-primary order parameters, such as antiferromagnetism or ferrimagnetism. In addition other types of primary order, such as ferroic arrangements of magneotelectric multipoles of which ferrotoroidicity is an example, have also been recently proposed.

Besides scientific interest in their physical properties, multiferroics have potential for applications as actuators, switches, magnetic field sensors or new types of electronic memory devices.

Those materials which combine multiple ferroic properties such as ferromagnetism, ferroelectricity and ferroelasticity are known as multiferroics. Simultaneous coexistence of at least two ferroic properties takes place in the same phase in multiferroics. It has the feasibility of exhibiting coupling between ferroelectricity and magnetism which is known as the magnetoelectric effect (ME). This ME enables the external electric field to change magnetization .

	Space invariant	Space variant
Time invariant	Ferroelastic	Ferroelectric
Time variant	Ferromagnetic	Ferrotoroidic

1. **Type-I Multiferroics:**

This type of multiferroics are older, more numerous and are good ferroelectrics. Above room temperature, the critical temperatures of the magnetic and ferroelectric transitions can be well. In these materials, the coupling between magnetism and ferroelectricity is unfortunately weak. Different origin of ferroelectricity and magnetism in type-I multiferroic are mostly due to different active subsystems of a material.

2. **Type-II Multiferroics:**

Due to the recent discovery of a novel class of multiferroics, there is the biggest excitement as ferroelectricity exists only in a magnetically ordered state and is caused by a particular type of magnetism. A nonzero electric polarization occurs in the low temperature phase. For example CuFeO2 with $T_c = T_N$.

Q6] B) A soap film 4×10^{-5}cm thick is viewed at angle of 35° to normal. Calculate wavelength of light in the visible spectrum which will be absent from the Reflected light ($\mu = 1.33$) (5)

Solution :-

$\mu = 1.33 \qquad t = 4 \times 10^{-5}\text{cm}$

$i = 35°$

$\mu = \frac{\sin i}{\sin r}$

$\sin r = \frac{\sin i}{\mu} = \frac{\sin 35}{1.33} = 0.43$

$r = 25.46$

$\cos r = 0.902$

Condition for darkness is $2\mu t \cos r = n\lambda$

Substitute values of n as 1,2,3,4…… we will get corresponding wavelengths those wavelengths which fall in the visible spectra will remain absent.

for $n = 1, \lambda_1 = 2 \times 1.33 \times 4 \times 10^{-5} \times 0.902 = 9597\text{AU}$

for $n = 2, \lambda_1 = 2 \times 1.33 \times 4 \times 10^{-5} \times \frac{0.902}{2} = 4798\text{AU}$

for $n = 3, \lambda_1 = 2 \times 1.33 \times 4 \times 10^{-5} \times \left(\frac{0.902}{3}\right) = 3199\text{AU}$

for $n = 4, \lambda_1 = 2 \times 1.33 \times 4 \times 10^{-5} \times \frac{0.902}{4} = 2399\text{AU}$

for $n = 5, \lambda_1 = 2 \times 1.33 \times 4 \times 10^{-5} \times \frac{0.902}{5} = 1919\text{AU}$

So wavelength corresponding to 4798 and 3199 AU will remain absent in the visible spectra

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Q6] C) The Coefficient (Rh) of semiconductor is $3.22 \times 10^{-4} m^3 c^{-1}$. Its resistivity is $9 \times 10^{-3} \Omega m$. Calculate the mobility and concentration of carriers. (5)

Solution:-

Since R_H is positive the given specimen is p type material, $R_H = \frac{1}{pe}$

$(p) = \frac{1}{R_H e} = \frac{1}{3.22 \times 10^{-4} \times 1.6 \times 10^{-19}} = 1.9 \times 10^{22} m^{-3}$

$$\text{mobility}(\mu) = \sigma_H R_H = \frac{R_H}{\rho_H} = \frac{3.22\times10^{-4}}{9\times10^{-3}} = 0.3577 \times 10^{-1}\ \text{m}^2\ /\text{V} - \text{s}$$
